OPTIMIZATION OF AIR INTAKE SYSTEM FOR INLINE-4 DIESEL ENGINE

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ABSTRACT

Air Intake System is a system that produces fresh and clean air to an engine for combustion process. Insufficient air into the combustion chamber will decrease the engine performance thus decrease power generated by the engine. For this thesis, the objective is to study the effect of pressure drop inside the air intake system. Simulation and experiment methods have been conducted in this study. Air intake system model that had been use in this study is the air intake system of Proton Waja and this study focus on optimization of the air box. Data that have been obtained from simulation analysis was used to fabricate an optimized design of an air box. This air box then will be tested on an experiment test. All the data from simulation and experiment testing were collected and analyze. From the analysis, by adding guide vane and bell mouth on a standard air box, the pressure drop can be decreased thus increase the air flow performance inside the air intake system. In further study, it was recommended to test the optimized air box on Proton Waja to see the actual performance increased.

ABSTRAK

Sistem Induksi Udara adalah satu sistem yang berperanan untuk membekalkan udara yang bersih dengan kuantiti yang mencukupi untuk dibakar di dalam kebuk pembakaran enjin. Kadar penyaluran udara yang kurang ke dalam enjin akan mengurangkan kadar keberkesanan pembakaran bahan bakar di dalam enjin seterusnya menyebabkan enjin tidak dapat menghasilkan kuasa yang maksimum. Tesis ini bertujuan untuk mengkaji kesan perbezaan tekanan di dalam sistem induksi udara. Kaedah yang telah digunakan di dalam kajian ini adalah kaedah simulasi dan eksperimen. Model sistem induksi udara yang digunakan di dalam kajian ini diambil daripada model kenderaan Proton Waja dan kajian ini mengfokuskan kepada kotak penapisan udara. Maklumat-maklumat yang diperoleh daripada analisis simulasi digunakan untuk membina sebuah kotak udara yang lebih baik dan diuji di dalam eksperimen. Maklumat- maklumat yang diperoleh daripada kajian simulasi dan eksperimen kemudiannya dikumpul dan dianalisa. Daripada analisa yang telah dijalankan, dengan pemasangan mulut loceng dan sirip pandu keatas sistem induksi udara yang asal dapat mengurangkan perbezaan tekanan di dalam sistem induksi udara. Kajian yang lebih terperinci disarankan bagi melihat keberkesanan sistem induksi udara yang telah dioptimumkan ini dengan ujian prestasi ke atas kereta Proton Waja.

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LIST OF SYMBOLS

h_L	Head loss
ε	Roughness
Re	Reynolds Number
K_L	Loss Coefficient
ΔP	Pressure Different
g	Constant Gravity
ρ	Density of Water
A_c	Area of The Cross Section
$\dot{m}$	Mass Flow Rate
$\dot{V}$	Volume Flow Rate
η_v	Engine Volumetric Efficiency
N	Engine Speed
Di	Engine Displacement
V	Velocity
Va	Engine Air Flowrate
f	Friction Factor
P_{atm}	Pressure Atmospheric
h	Elevation

LIST OF ABBREVIATIONS

AIS	Air Intake System
CFD	Computational Fluid Dynamics
3D	Three Dimensional
2D	Two Dimensional
CAD	Computer-Aided Design
SOHC	Single Over Head Cam
RPM	Revolution Per Minute

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The main function of an air intake system is to supply the engine with good quality of air with a correct amount to be burned inside combustion chamber. It improves the combustion efficiency and also reduces air pollution. The important characteristic on designing an intake system is its flow through the system. The flow efficiency of the intake system has a direct impact on the power the engine can deliver. Decreasing the pressure drop inside the intake system can smooth the air flow and increase the flow efficiency.

The system that cleans the air and guides it into the cylinders is called an Air Intake System (AIS). The AIS may be divided into four main parts, which are air box, intake plenum, intake manifold, and intake port. Incoming dirty air is guided into air box section where a filter is located that cleans the polluted air and other particles from entering the cylinders. Clean air then will enter the cylinders through intake plenum, intake manifold, and intake port.

In order to optimize the AIS, understanding on flows and pressure drop through the system is essential. Computational Fluid Dynamics (CFD) is considered to be the most cost-effective solution for flow analysis of the intake system.

This project will develop an optimize air box design for air intake system for Proton Waja engine. Three different design of optimize air box will be tested under various conditions of flow behavior under flow bench test and CFD analysis.

1.2 PROBLEM STATEMENT

A good quality of air increases an engine's efficiency and performance. Dirty air can damage the cylinder and shorten the engine life. Therefore, air intake system plays major role on providing clean air into the combustion chamber. Incoming dirty air is guided into the air box where a filter is located that cleans the polluted air and hinders soot and other particles before entering the combustion chamber.

Smooth air flow through the air box is important to decrease the total pressure of air entering the system. The geometry of an intake performance is related to the loss coefficient, typically identified as $K_{L.}$, which represents the fraction of the dynamic head lost in the duct. This loss can be easily controlled by proper design of the inlet duct.

Good design of air box with fewer pressure drops is one of the important thing need to figure out and studied. High pressure drop inside the intake system will cause the engine to receive improper value or air thus decreases the engine performance. An air box designed with less restriction area will smooth the air flow and reduce the pressure drop inside the system.

1.3 OBJECTIVE

Generally, the objectives to be achieved in this project are stated below:

i. To develop 3D model of an intake system.
ii. To observe the pressure drop inside the air intake system.
iii. To develop designed air box for optimization of an air intake system.

1.4 SCOPE

The project is focused on:

i. Literature review.
ii. Develop air box designs with optimum air flow.
iii. Simulate the model by using Computational Fluid Dynamic (CFD) and model test on a steady flow bench test.
iv. Result comparing and writing.

1.5 HYPOTHESIS

As the engine speed is related to the air flow rate inside the air intake system, the increment in engine speed will increase the air flow rate thus affect the flow behavior inside the intake system. As the restriction area inside the system is related to the pressure drop, wider area of restriction area will increase pressure drop for certain flow rate. As higher engine speed creates higher flow rate, the smaller restriction and smooth surface will decrease the pressure drop inside the air intake system.

1.6 METHODOLOGY

i. Stage 1 : Literature study

Make review on literature study involving project title.

ii. Stage 2 : 3D Modeling

3D modeling of the air box design

iii. Stage 3 : Boundary condition setting simulation

Set up boundary condition for simulation analysis.

iv. Stage 4 : Simulating analysis by using CFD software

Simulating analysis using FLUENT

v. Stage 5 : Model fabrication and flow bench test

Model testing on flow bench test

vi. Stage 6 : Analysis of simulation and experiment result

Analysis result from simulation and experiment

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter presents a review of literature on the efforts relating to automotive air intake system, and the pressure drop inside an air intake system. It attempts to establish what the factors are affecting the performance of intake system and how this intake system affected the car engine performance. The discussions are focused on the flow management in the intake system as a tool to optimize the air intake system. The previous study on optimization of air intake system also include in this study.

2.2 AIR INTAKE SYSTEM

The basic function of engine air intake system is to provide the engine with a fresh air-fuel mixture for combustion process inside the combustion chamber as possible (Ceviz M.A., 2010). Different engine operation requires different air intake system. In other words, a vehicle that is used for everyday purpose cannot have the same intake system as a racing vehicle. Racing engines require maximum volumetric efficiency for increase power and torque, thus the fuel consumption may increase. Daily use vehicles seldom require top-end power, thus economy and drivability at lower speeds are more important in this instance (Makgata, 2005). The air intake system development is guided by demands from different disciplines. The requirements of each discipline itself were already taken into consideration in the past. The development of future air intake systems needs to focus on the link between the different disciplines as well (Holger, 1999).

Most of engine air intake systems consist of dirty pipe, air box, air cleaner, clean pipe, intake manifold plenum, and intake manifold runner. The length of air intake system for a car can reach up to 1 meter length. The air through these air intake systems may face great challenge of pressure drop, thus give a great challenge for induction system designer to minimize the pressure drop inside air intake system. Some important design criteria on developing intake system are low air flow resistance and good distribution of air (Ceviz, M.A, 2007). A positive pressure at the end of the frontal dirty pipe would help to overcome the drawback. Thus, most of the car manufacturer had design to put the dirty pipe at the front of the vehicle to increase the capability of the engine to consume more air from the frontal area. In fact, drawing air from the front of the vehicle can reduce the interior noise contribution from the intake orifice (Rizalman, 2008). Introduction on rib pattern inside the air box also can reduce the sound noise inside the air box and increase the part stiffness (John, 1997).

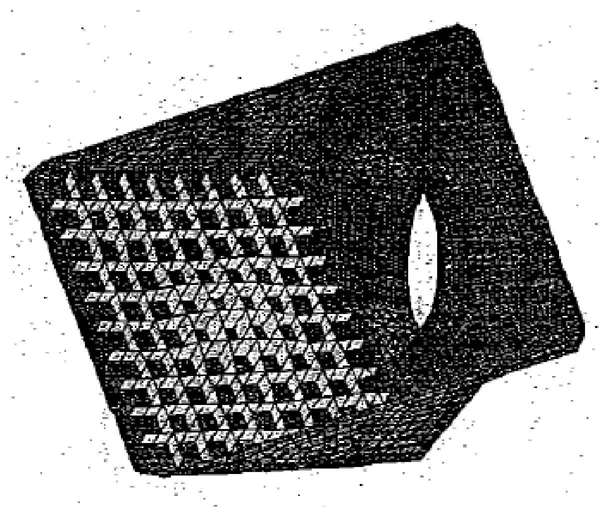


Figure 2.1: Rib pattern inside air box.

Source: John (1997)

For diesel engine, this is pretty straightforward. Air comes in the air filter housing, passes through the air filter then through the intake manifold, then the kinetic energy of the fluid resulting in turbulence causes rapid mixing of fuel and air (Murali, 2010), and is drawn into the cylinder. The most advanced part of the system was an air temperature sensor in the air intake. It was used to measure the air temperature and, by opening and closing a flap, allow cool air in through the air horn or heated air piped in from around an exhaust manifold. The reason the intake tube is long is to get the air moving in a fairly steady, coherent stream. It then passes through the air filter and then through an Air Flow Meter (Ceviz M.A., 2010)**.**

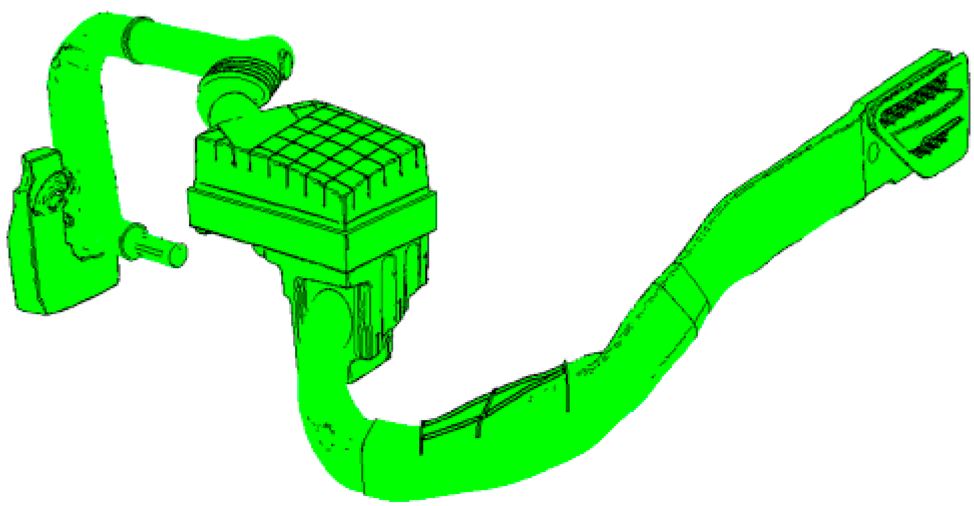


Figure 2.2: 3D geometry of air intake system.

Source: Rizalman et al (2008)

The intake system of an engine has three main functions. Its first and usually most identifiable function is to provide a clean and fresh air free from debris to the engine by method of filtering. Two other characteristics that are important for engineers to design the intake system are its flow and acoustic performance (D. Ramasamy et al, 2010) (Hyunsoo et al, 2009). The flow efficiency of the intake system has a direct impact on the power of the engine is able to deliver. The alternating pressure induced in the induction system and in the air box causes the specific radiated sound of the whole intake system and create noise (Wolfgang, 2002). The acoustic performance is very important because it plays major role on giving noise level on vehicle during a pass-by test. Effect of adding more guide vane placement on a critical region may improve the AIS design even further (D. Ramasamy et al, 2010).

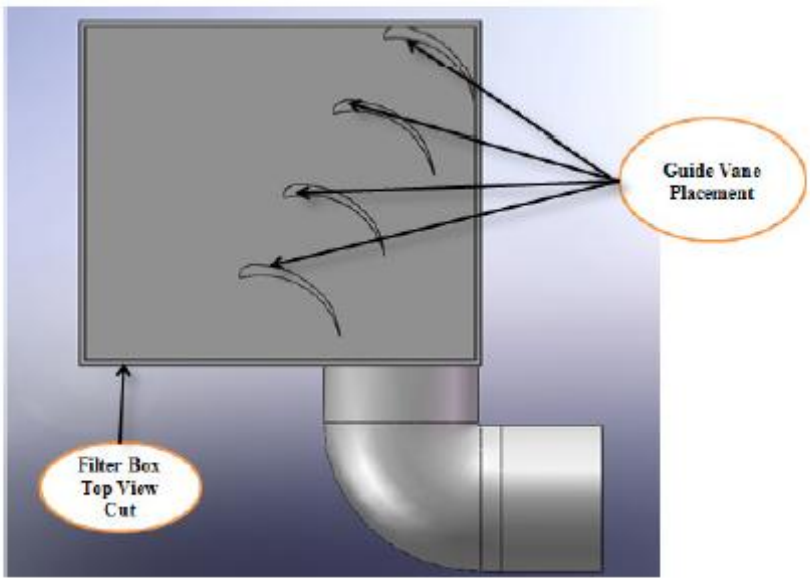


Figure 2.3: Guide vane placement by previous study.

Source: D. Ramasamy (2010)

To have effective cleaning of air from filter, it was suggested to have uniform velocity of air pass through filter (R. Yerram et al, 2006). In order to avoid the recirculation inside air box, baffle was use which would guide the flow to avoid recirculation. Baffle installation in the inlet plenum below the filter has enhanced the efficiency by guiding the flow and reducing the pressure drop significantly (R. Yerram et al, 2006) (A. Aroussi, 2003). As flow increases, pressure drop across filter bed also increases (A. S. Patil, 2005). High value of pressure drop will decrease the engine efficiency because the amount of air supplied to the engine is not enough thus retard the combustion process. In fact, it causes more emission to occur (Rizalman et al, 2009). An uneven air distribution leads to less volumetric efficiency, power loss and increased fuel consumption (Safari et al, 2003).

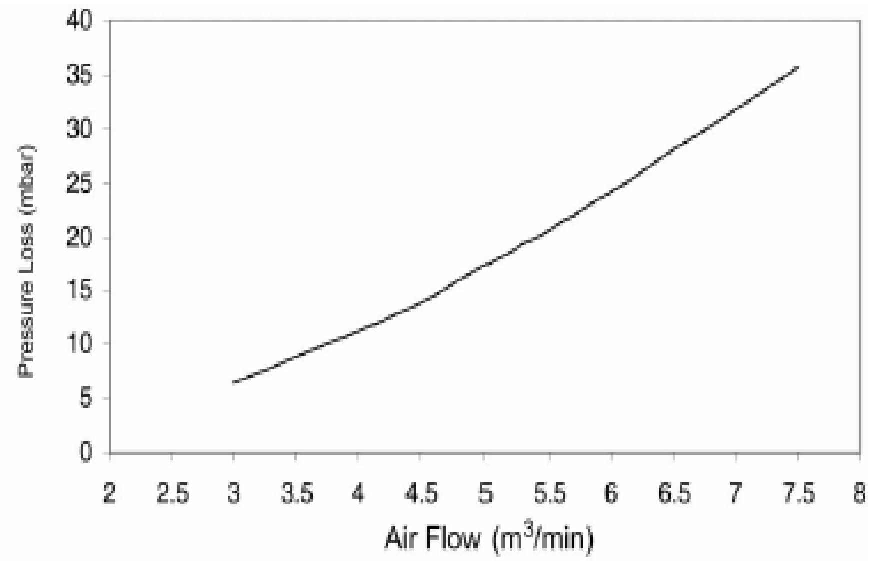
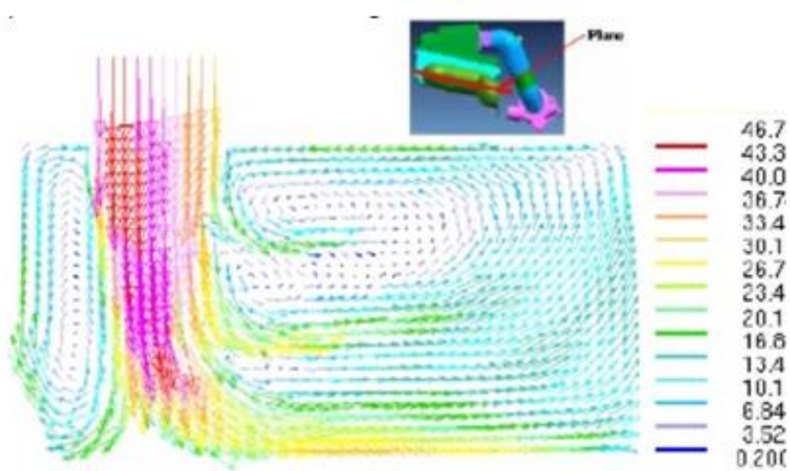
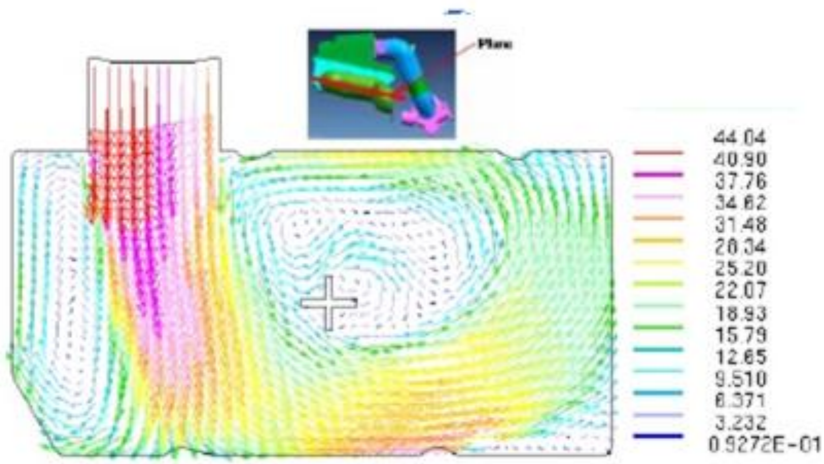


Figure 2.4: Pressure drop vs Airflow for a Typical Dry Air Filter in fresh condition

Source: A. S. Patil, (2005)



(a)



(b)

Figure 2.5: Velocity vector plot: (a) with baffle (guide vane) installation; (b) without baffle (guide vane) installation

Source: R. Yerram (2006)

Air intake systems employ specially-shaped intake tubes designed to straighten airflow as much as possible while looking great in engine compartment. These pipes are typically mandrel-bent, a process that doesn't crimp the pipe diameter at the bend. Special care is given to locating the intake tube, air box and filter in the position that best fosters maximum performance. The materials used are also selected with optimum engine conditions in mind. Near outlet plenum exit, flow was separating and recirculating at both the ends. To avoid separation and recirculation in this region, a bell-mouth was introduced (R. Yerram et al, 2006).